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Influences of Masonry Infill Wall, Tie Beam and RCC Bracing on Soft Storey Mechanism

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ABSTRACT: The presence of infill wall in the building gives better behavior under lateral loads. Engineers believe that ignoring infill effect gives conservative design. For multistoried structures, the consideration of effect of bottom storey under seismic forces would be an important parameter. As per IS 1893 (Part-I) :2002 the columns and beams of the soft storey are to be designed for 2.5 times the storey shear and moments calculated under the seismic load of a bare frame (i.e. without considering infill effect). In this paper model is studied to investigate the magnification factor for various load combinations considering peripheral masonry infill wall only, peripheral masonry infill wall along with tie beams and RCC X bracings under seismic effect. The Equivalent diagonal strut method is used to calculate the width of infill strut by FEMA approach. The R.C.C. building model (P+7) has been prepared using ETAB software. The Seismic Coefficient Method has been performed for the analysis of various models. The results of investigations and their conclusions are discussed below.

Index Terms: Base shear, Displacement, Equivalent diagonal strut, Infill wall, Tie beam, R.C.C. X-Bracing, Load combinations, Magnification factor, Soft Story.

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1 INTRODUCTION

Currently India is a rapidly urbanizing country which leads to acquisition of land under different mega structures. The Reinforced Concrete (RC) Frame building is one of the under category field which is the current scope of construction in India. Now days due to the limitations of the horizontal development of the building, it has become necessary to grow vertically (Multi-storey, Sky scrapers etc.). Hence, due to higher height of the building, the effect of earthquake plays a dominant role for mechanism of structural parameters. One of the major considerations in high rise building is the 'Soft storey'. According to Indian standard code 1893 (Part-I) : 2002 clause 4.20 page no.10 a soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above. The soft storey may be in the form of vehicle parking (Refer Fig.1), for Commercial shop purpose, Intermediate soft storey for firefighting purpose etc.

Fig.1.Typical Image of Soft Storey

The significant use of this storey is functionally, but from a seismic performance point such a building is considered to have increased vulnerability. From the past earthquakes it is found that major failure occurred in the soft storey floor. Therefore it is necessary to withstand the soft storey under lateral loads with sufficient strength and stiffness and adequate ductility. The soft storey can be strengthened by using the structural and/or non-structural element like provision of RCC bracings, steel bracings, shear wall, peripheral tie beam, provision of brick masonry infill panels or combinations. According to Indian standard code 1893 (Part-I) : 2002 clause 7.10.3 (a) page no.27 states that, the columns and beams of the soft storey are to be designed for 2.5 times the storey shear and moments calculated under the seismic loads of a bare frame (i.e. without considering infill effect). The factor 2.5 is called as magnification factor. The magnification factor is supposed to be compensating for stiffness discontinuity. The F. Demir's and M. Sivri (2002) approach is used to calculate the masonry infill strut width. Indian standard code is silent about considering the provision of peripheral infill effect, peripheral infill effect along with tie beams or RCC bracings in soft storey for magnification factor.

2 OBJECTIVE OF THE WORK

The objective behind the work descript below:

i) To check the applicability of magnification factor 2.5 with considering the provisions like peripheral infill effect, peripheral infill effect with peripheral tie beams and peripheral infill effect with peripheral RCC bracings in OGS.

ii) To check the applicability of magnification factor 2.5 with various load combinations given in IS code.

3 VARIOUS LOAD COMBINATIONS

As per IS code 1893 (Part-I): 2002 clause 6.3.1.2 page no.13

1) 1.5 (DL + LL) 2) 1.2 (DL + LL ± EQx)

3) 1.2 (DL + LL ± EQy) 4) 1.5 (DL ± EQx)

5) 1.5 (DL ± EQy) 6) 0.9 DL ± 1.5 EQx

7) 0.9 DL ± 1.5 EQy

By considering the above load combinations the Magnification factor has been investigated.

4 STRUCTURAL FRAMING

The presence of only masonry infill walls, masonry infill wall along with Tie beam or RCC X-bracing in a framed building not only enhance the lateral stiffness but also alters the transmission of forces in beams and columns as compared to the bare frame. In a bare frame, the resistance to lateral forces is due to the development of bending moments and shear force in the beam and column through the rigid jointed action.

5 FRAMING SYSTEM CONSIDERED FOR ANALYSIS

For the analysis purpose four models are prepared (see Table 1) namely,

TABLE 1 METHODOLOGY

Model No.	Abbreviation	Descriptions
Model I	M_I	Bare frame
Model II	M_{II}	Peripheral masonry infill in Bottom Storey
Model III	M_{III}	Peripheral masonry infill wall along with tie beams in Bottom Storey
Model IV	M_{IV}	Peripheral masonry infill wall along with RCC bracings in Bottom Storey

The bottom storey Columns & beams being grouped according to their position as follows (See Table 2 and 3, refer Fig.3),

TABLE 2 BEAM GROUPING

Group	Location	Beam No.
G - I	Corner Beams	B_1, B_3, B_{16}, B_{18-19}, B_{23}, B_{34}, B_{38}
G - II	Peripheral Beams 1	B_2, B_4, B_{6-7}, B_{9-10}, B_{12-13}, B_{15}, B_{17}
G - III	Peripheral Beams 2	B_{20-22}, B_{24}, B_{28-29}, B_{33}, B_{35-37}
G - IV	Central Beams	B_5, B_8, B_{11}, B_{14}, B_{25-27}, B_{30-32}

TABLE 3 COLUMN GROUPING

Group	Location	Column No.
G - I	Corner Columns	C_1, C_4, C_{21}, C_{24}
G - II	Peripheral Columns	C_{2-3}, C_5, C_{8-9}, C_{12-13}, C_{16-17}, C_{20}, C_{22-23}
G - III	Central Columns	C_{10-11}, C_{14-15}

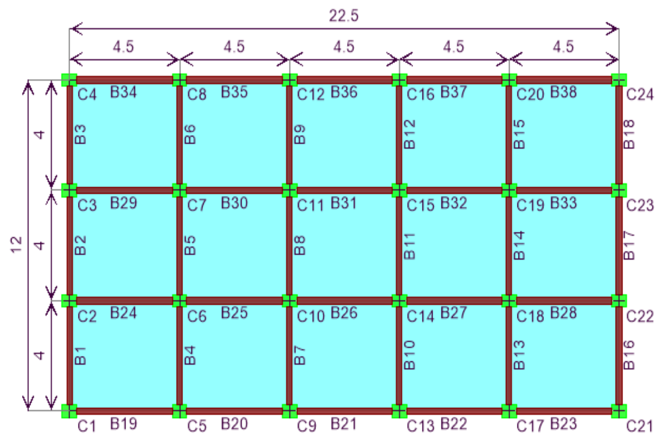

Fig.3.Plan of Building

6 PARAMETRIC CONSIDERATIONS FOR BUILDING MODEL

For the analysis purpose the following structural and seismic data has been considered (See Table 4)

TABLE 4 DESCRIPTION OF BUILDING MODEL

SR.NO.	Building Parameters	Description
1	Type of Frame	SMRF
2	Seismic Zone	V
3	Importance Factor (I)	1
4	Response Reduction Factor	5
5	Type of Soil	Hard (Type I)
6	Damping of Structure	5%
7	Spacing of Frame,	
	i) In X - Direction	4.50 m
	ii) In Y – Direction	4.00 m
8	Loadings,	
	i) Dead Load	Self-weight of structural elements
	ii) Floor Finishes	1 KN/m²
	iii) Live Load	4 KN/m²
9	Storey	G + 7 (5 x 3 Bay)
	i) Open Ground Storey Height	4.00 m

(Continuous…….)

	ii) Upper Stories Height	3.00 m (Each)
10	Thickness of Slab	0.150 m
11	Size of Beam	230 X 450 mm
12	Size of Peripheral Tie Beam in Open Ground Storey	230 X 450 mm
13	Size of Peripheral X-Bracing in Open Ground Storey	230 X 450 mm
14	Column Sizes,	
	i) First and Second floor	450 X 600 mm
	ii) Third and Fourth floor	400 X 600 mm
	iii) Fifth and Sixth floor	350 X 600 mm
	iv) Seventh and Eighth floor	300 X 600 mm
15	Thickness of Inner and Outer Brick Wall	230 mm
16	Grade of Concrete	M25
17	Grade of Reinforcement	Fe 500
18	Density of Concrete	25 KN/m^3
19	Density of Brick Masonry	20 KN/m^3
20	Poisson Ratio of concrete	0.2
21	Poisson Ratio of Brick Masonry	0.15
22	Modulus of Elasticity of Concrete	2.50×10^8 KN/m^2
23	Modulus of Elasticity of Brick Masonry	1.25×10^6 KN/m^2
24	Coefficient of Thermal Expansion of Concrete	9.90×10^{-6}
25	Coefficient of Thermal Expansion of Brick Masonry	5.50×10^{-3}

7 Results

For various forces acting on bottom storey column cross section as shown in Fig.4 under various load combinations for R1, R2 and R3 are tabulated and graphically represented as below,

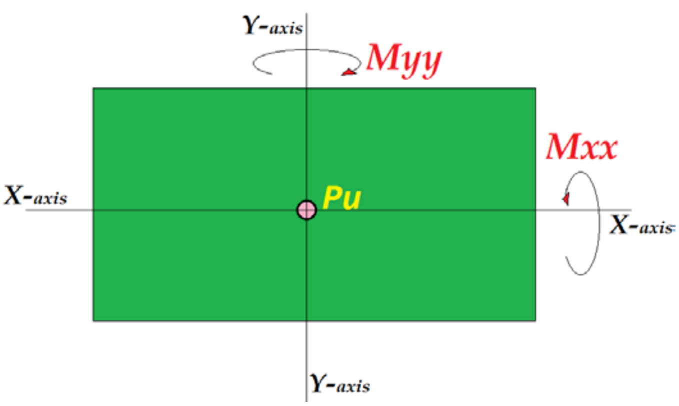

Fig.4.Forces Acting on Column Cross Section

$R1 = M_{II} / M_I$ Pu = Axial Force

$R2 = M_{III} / M_I$ Myy = Moment about yy-axis

$R3 = M_{IV} / M_I$ Mxx = Moment about xx-axis

7.1 The magnification factors of Soft Storey Columns

7.1.1 For Group I column

TABLE 5 AXIAL FORCE RATIOS

SR.NO.	Load combinations	R1	R2	R3
1	1.5(DL+LL)	1.65	1.16	1.47
2	1.2(DL+LL+EQx)	1.27	1.11	1.26
3	1.2(DL+LL-EQx)	1.35	1.14	1.28
4	1.2(DL+LL+EQy)	1.18	1.08	1.17
5	1.2(DL+LL-EQy)	1.26	1.1	1.19
6	1.5(DL+EQx)	1.33	1.1	1.28
7	1.5(DL-EQx)	1.39	1.12	1.31
8	1.5(DL+EQy)	1.21	1.36	1.18
9	1.5(DL-EQy)	1.28	1.1	1.17
10	0.9DL+1.5EQx	1.4	1.08	1.35
11	0.9DL-1.5EQx	1.48	1.12	1.37
12	0.9DL+1.5EQy	1.24	1.03	1.2
13	0.9DL-1.5EQy	1.32	1.06	1.22

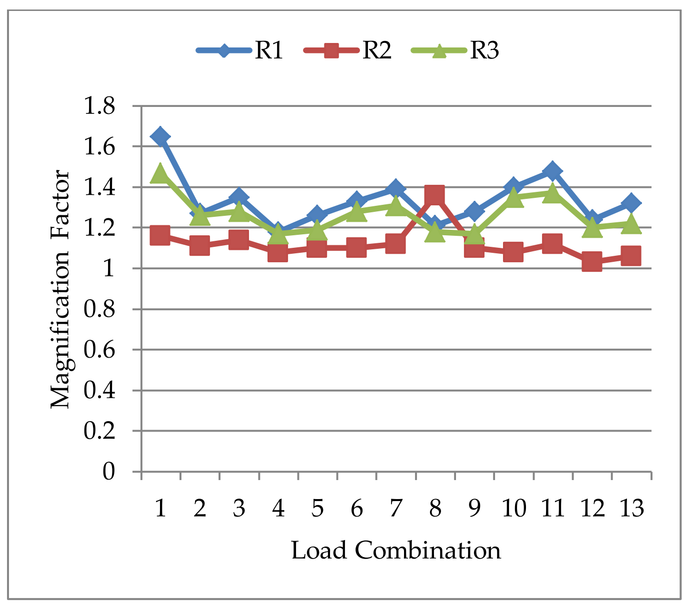

Fig.9.Axial force ratio

TABLE 6 MOMENT RATIO ABOUT YY-AXIS

SR.NO.	Load combinations	R1	R2	R3
1	1.5(DL+LL)	0.9	0.16	1.02
2	1.2(DL+LL+EQx)	0.14	0.14	1.05
3	1.2(DL+LL-EQx)	0.17	0.14	1.05
4	1.2(DL+LL+EQy)	0.34	0.062	0.26
5	1.2(DL+LL-EQy)	1.06	0.68	0.25
6	1.5(DL+EQx)	1.22	0.09	0.57
7	1.5(DL-EQx)	1.63	0.1	0.56
8	1.5(DL+EQy)	1	0.63	0.25
9	1.5(DL-EQy)	1.06	0.58	0.25
10	0.9DL+1.5EQx	1.83	0.14	0.55
11	0.9DL-1.5EQx	0.54	0.12	0.05
12	0.9DL+1.5EQy	0.83	0.5	0.45
13	0.9DL-1.5EQy	0.83	0.14	0.45

TABLE 7 MOMENT RATIO ABOUT XX-AXIS

SR.NO.	Load combinations	R1	R2	R3
1	1.5(DL+LL)	3.78	0.89	1.48
2	1.2(DL+LL+EQx)	0.23	0.62	0.2
3	1.2(DL+LL-EQx)	1.34	0.67	0.2
4	1.2(DL+LL+EQy)	1.18	1.03	1.17
5	1.2(DL+LL-EQy)	1.26	1.06	1.19
6	1.5(DL+EQx)	1.28	0.64	0.18
7	1.5(DL-EQx)	1.33	0.67	0.18
8	1.5(DL+EQy)	1.04	0.88	1.01
9	1.5(DL-EQy)	0.46	0.38	0.44
10	0.9DL+1.5EQx	1.35	0.54	0.14
11	0.9DL-1.5EQx	1.32	0.65	0.16
12	0.9DL+1.5EQy	1.23	0.98	1.17
13	0.9DL-1.5EQy	1.32	1.01	1.2

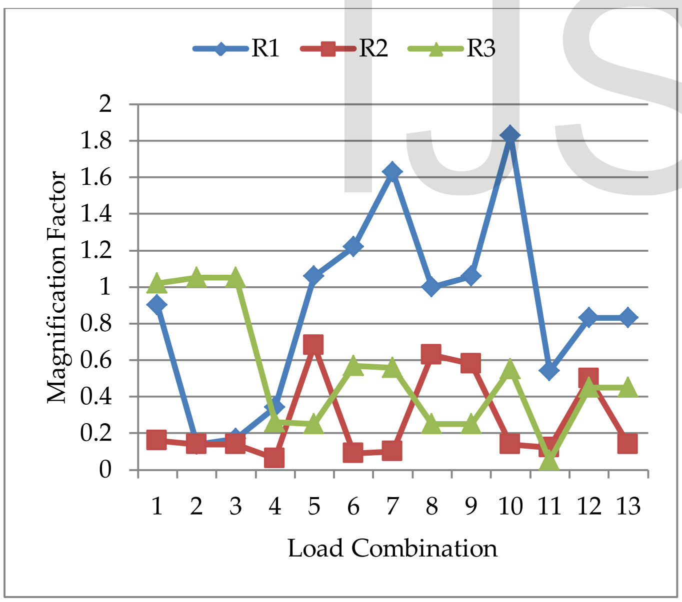

Fig.10.Moment ratio about yy-axis

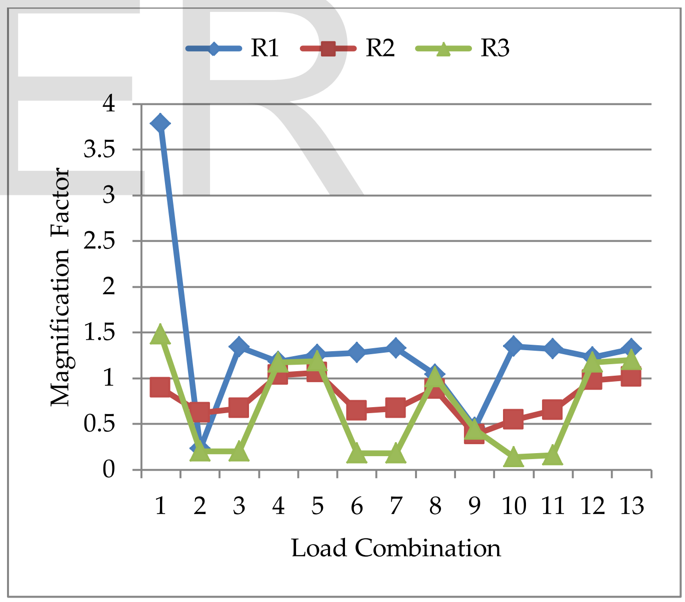

Fig.11.Moment ratio about xx-axis

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7.1.2 For Group II columns

TABLE 8 AXIAL FORCE RATIOS

SR.NO.	Load combinations	R1	R1	R3
1	1.5(DL+LL)	0.9	1.11	0.99
2	1.2(DL+LL+EQx)	1.03	1.21	1.18
3	1.2(DL+LL-EQx)	1.19	1.05	1.04
4	1.2(DL+LL+EQy)	1.45	1.32	1.21
5	1.2(DL+LL-EQy)	1.45	1.63	1.28
6	1.5(DL+EQx)	1.48	1.27	1.23
7	1.5(DL-EQx)	0.98	1.06	0.65
8	1.5(DL+EQy)	1.56	1.36	1.37
9	1.5(DL-EQy)	1.17	1.05	1.03
10	0.9DL+1.5EQx	1.76	1.4	1.53
11	0.9DL-1.5EQx	1.31	1.04	1.2
12	0.9DL+1.5EQy	1.8	1.55	1.53
13	0.9DL-1.5EQy	1.18	1.01	1.05

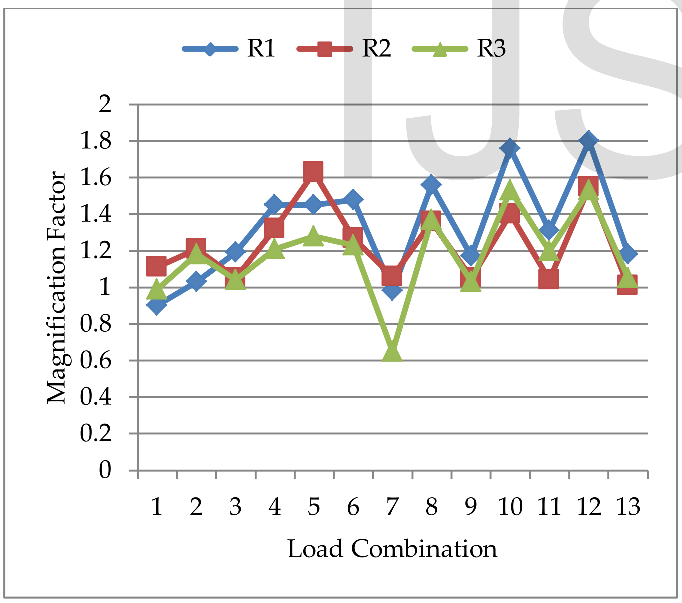

Fig.12.Axial force ratio

TABLE 9 MOMENT RATIO ABOUT YY-AXIS

SR.NO.	Load combinations	R1	R2	R3
1	1.5(DL+LL)	0.85	0.15	1.07
2	1.2(DL+LL+EQx)	0.51	0.06	0.62
3	1.2(DL+LL-EQx)	0.51	0.06	0.71
4	1.2(DL+LL+EQy)	1.02	0.54	1.27
5	1.2(DL+LL-EQy)	1.05	0.58	1.61
6	1.5(DL+EQx)	1.13	1.11	0.63
7	1.5(DL-EQx)	1.14	1.13	0.71
8	1.5(DL+EQy)	0.99	0.63	0.47
9	1.5(DL-EQy)	1.02	0.55	0.49
10	0.9DL+1.5EQx	1.78	0.7	0.64
11	0.9DL-1.5EQx	0.65	0.072	0.71
12	0.9DL+1.5EQy	0.9	0.54	1.48
13	0.9DL-1.5EQy	0.8	0.53	0.97

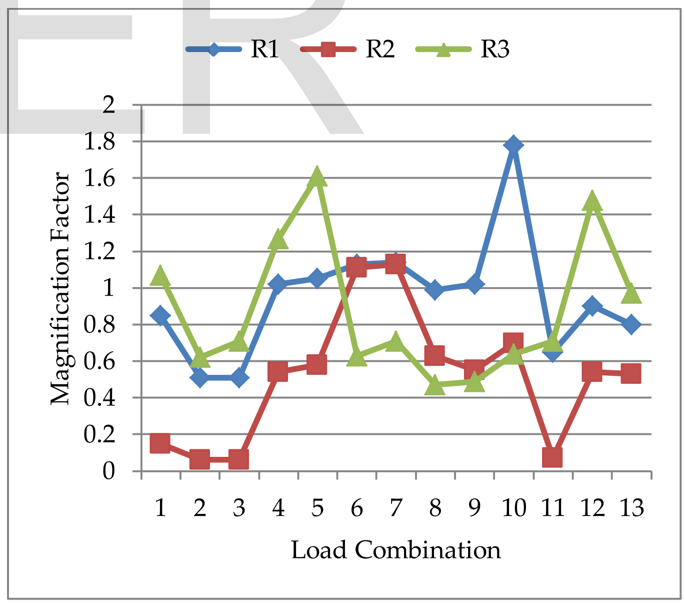

Fig.13.Moment ratio about yy-axis

TABLE 10 MOMENT RATIO ABOUT XX-AXIS

SR.NO.	Load combinations	R1	R2	R3
1	1.5(DL+LL)	2.39	0.1	0.99
2	1.2(DL+LL+EQx)	1.28	0.87	0.22
3	1.2(DL+LL-EQx)	1.36	0.96	0.23
4	1.2(DL+LL+EQy)	1.145	0.25	1.21
5	1.2(DL+LL-EQy)	1.45	0.27	1.28
6	1.5(DL+EQx)	1.36	0.89	0.19
7	1.5(DL-EQx)	1.37	1	0.21
8	1.5(DL+EQy)	0.56	0.26	0.5
9	1.5(DL-EQy)	0.46	0.26	0.5
10	0.9DL+1.5EQx	1.2	0.85	0.2
11	0.9DL-1.5EQx	1.42	1.4	0.2
12	0.9DL+1.5EQy	1.79	0.43	1.54
13	0.9DL-1.5EQy	1.18	0.44	1.08

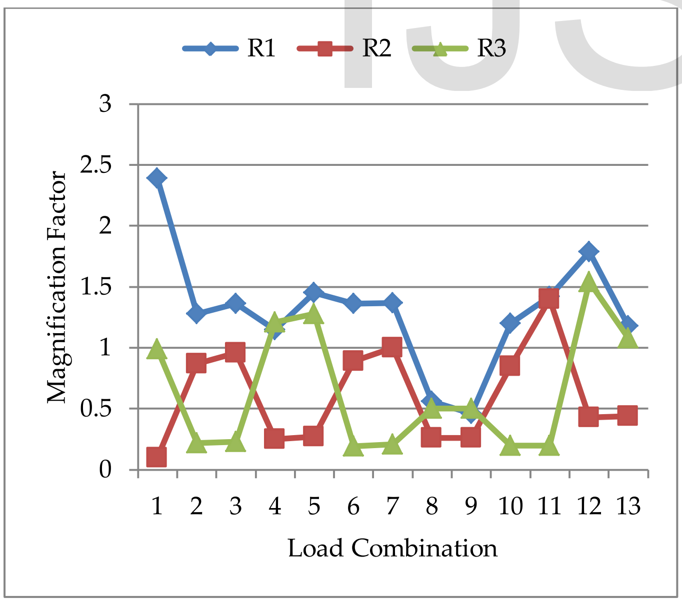

Fig.14.Moment ratio about xx-axis

7.1.3 For Group III columns

TABLE 11 AXIAL FORCE RATIOS

SR.NO.	Load combinations	R1	R2	R3
1	1.5(DL+LL)	1.03	1.02	1.03
2	1.2(DL+LL+EQx)	1.03	1.03	1.03
3	1.2(DL+LL-EQx)	1.03	1.03	1.02
4	1.2(DL+LL+EQy)	1.04	1.04	1.04
5	1.2(DL+LL-EQy)	1.01	0.83	1.03
6	1.5(DL+EQx)	1.06	1.06	1.05
7	1.5(DL-EQx)	1.06	1.06	0.54
8	1.5(DL+EQy)	1.07	1.06	1.06
9	1.5(DL-EQy)	1.03	1.06	1.06
10	0.9DL+1.5EQx	1.06	1.06	1.04
11	0.9DL-1.5EQx	1.05	1.06	1.05
12	0.9DL+1.5EQy	1.08	1.07	1.06
13	0.9DL-1.5EQy	1.01	1.06	1.07

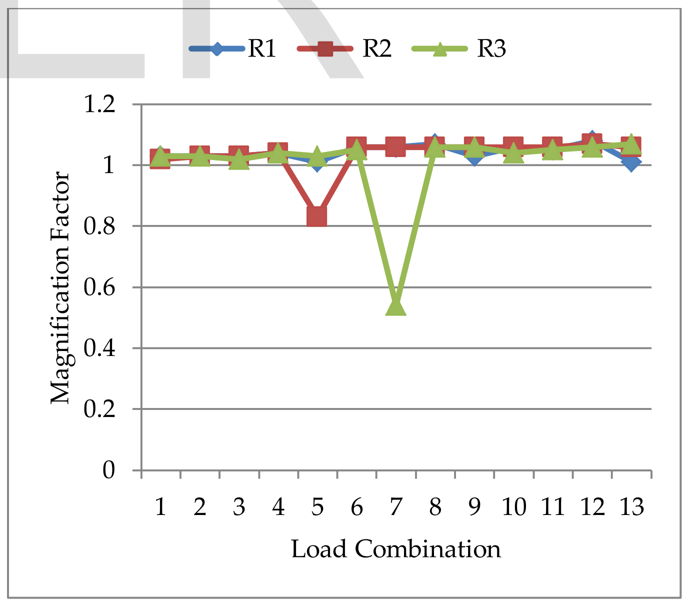

Fig.15.Axial force ratio

TABLE 12 MOMENT RATIO ABOUT YY-AXIS

SR.NO.	Load combinations	R1	R2	R3
1	1.5(DL+LL)	1.04	0.62	0.62
2	1.2(DL+LL+EQx)	0.47	0.03	0.002
3	1.2(DL+LL-EQx)	0.47	0.03	0.02
4	1.2(DL+LL+EQy)	1.03	0.54	0.25
5	1.2(DL+LL-EQy)	1.08	0.57	0.25
6	1.5(DL+EQx)	1.08	0.07	0.004
7	1.5(DL-EQx)	1.08	0.07	0.16
8	1.5(DL+EQy)	1.04	0.54	0.25
9	1.5(DL-EQy)	1.08	0.57	0.25
10	0.9DL+1.5EQx	0.53	0.04	0.01
11	0.9DL-1.5EQx	0.53	0.034	1.03
12	0.9DL+1.5EQy	0.84	0.44	0.27
13	0.9DL-1.5EQy	0.86	0.46	0.4

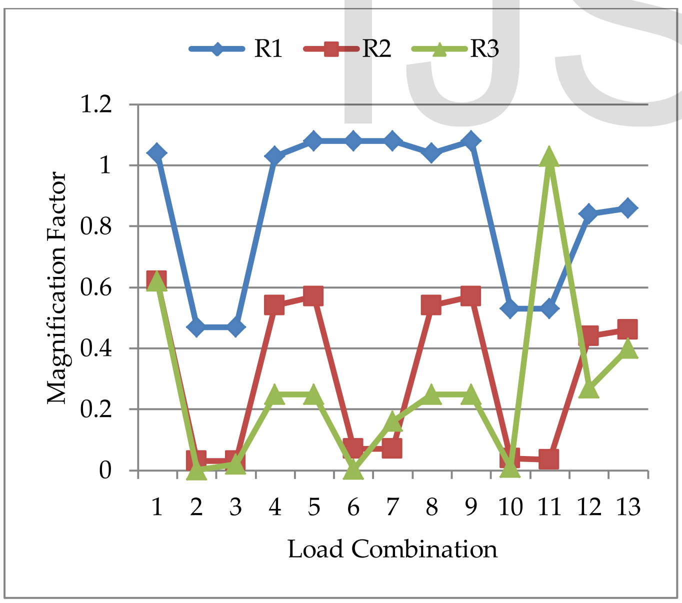

Fig.16.Moment ratio about yy-axis

TABLE 13 MOMENT RATIO ABOUT XX-AXIS

SR.NO.	Load combinations	R1	R2	R3
1	1.5(DL+LL)	1.48	1.32	1.00
2	1.2(DL+LL+EQx)	1.3	0.54	0.31
3	1.2(DL+LL-EQx)	1.38	0.6	0.31
4	1.2(DL+LL+EQy)	1.05	1.04	1.05
5	1.2(DL+LL-EQy)	1.01	0.8	1.03
6	1.5(DL+EQx)	1.31	0.55	0.23
7	1.5(DL-EQx)	1.37	0.59	0.2
8	1.5(DL+EQy)	1.07	1.06	1.06
9	1.5(DL-EQy)	1.07	1.04	1.06
10	0.9DL+1.5EQx	1.57	0.56	0.22
11	0.9DL-1.5EQx	1.36	0.58	0.17
12	0.9DL+1.5EQy	1.08	1.07	0.13
13	0.9DL-1.5EQy	1.01	1.06	1.08

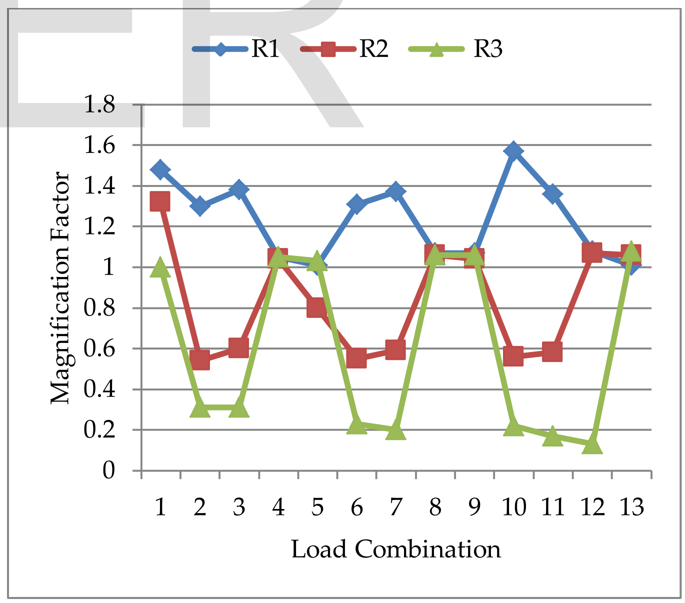

Fig.17.Moment ratio about xx-axis

7.2 The Magnification factors for Soft Storey Beams

7.2.1 Shear Force

TABLE 12 SHEAR FORCE RATIOS OF OPEN GROUND STOREY BEAMS

Group I	R1	R2	R3
G - I	1.058	0.721	4.4
G - II	0.92	0.7	4.07
G - III	1.065	0.78	3.41
G - IV	1.054	0.78	4.07

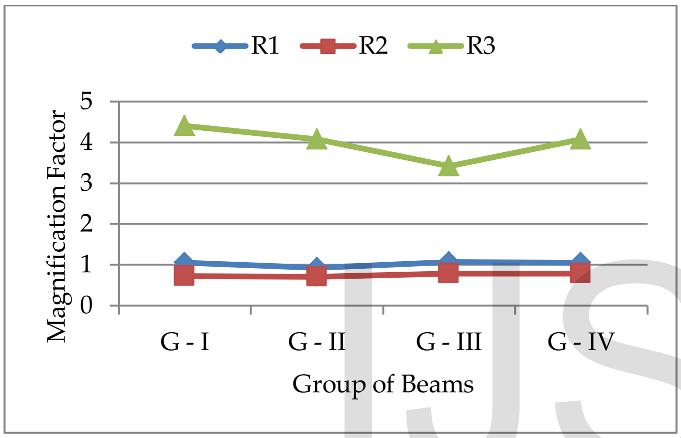

Fig.19.Shear force ratios of open ground storey beams

7.2.2 Moments

TABLE 11 MOMENT RATIOS OF OPEN GROUND STOREY BEAMS

Group I	R1	R2	R3
G - I	1.09	0.58	1.09
G - II	0.88	0.57	0.88
G - III	1.094	0.64	1.42
G - IV	1.09	0.65	0.69

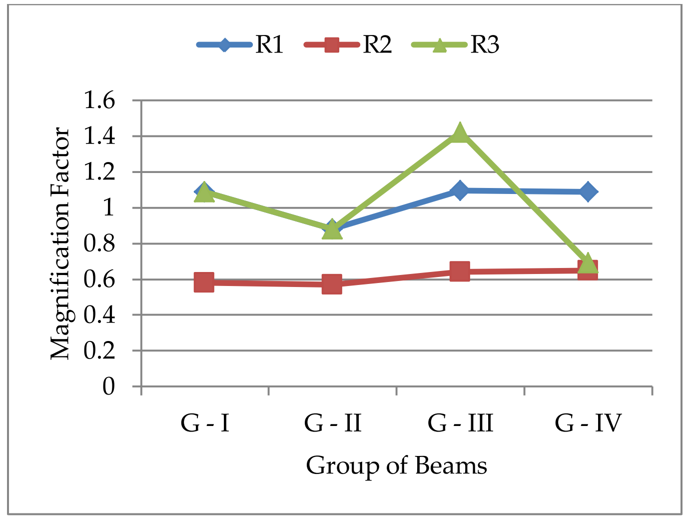

Fig.18.Moment ratios of open ground storey beam

7.3 Storey Base Shear and Displacement

7.3.1 Base Shear

TABLE 13 BASE SHEARS OF DIFFERENT MODELS

Direction	Bare	Infill	Infill + Tie	Infill +bracing
EQX	1295.6	2477.18	2512.85	2502.98
EQY	1295.6	1804.19	1845.09	1809.85

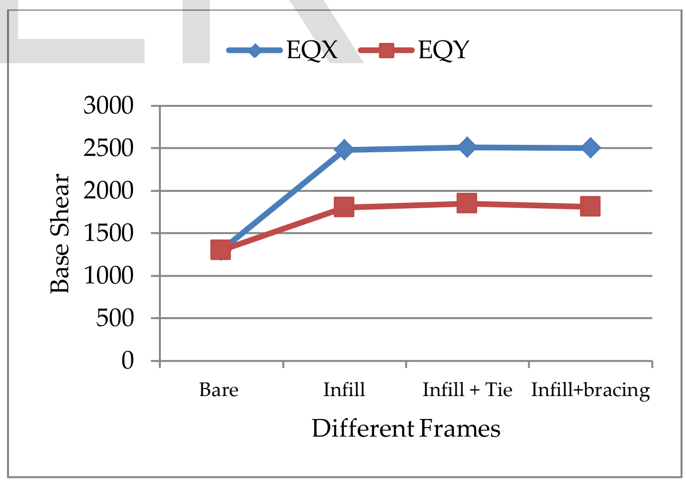

Fig.20.Base shear of different models

7.3.2 Displacement

7.3.2.1 X-Direction

TABLE 14 DISPLACEMENTS IN X-DIRECTION OF DIFFERENT MODELS

Storey	Bare	Infill	Infill + Tie	Infill +bracing
S - 1	4.4	5.4	2.36	1.49
S - 2	9.64	10.5	4.7	5.32

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S - 3	15.26	15.45	7.05	10.06
S - 4	20.71	20.17	9.33	14.76
S - 5	25.79	24.62	11.47	19.18
S - 6	30.12	28.42	13.31	22.98
S - 7	33.5	31.41	14.74	25.98
S - 8	35.66	33.3	15.67	27.86

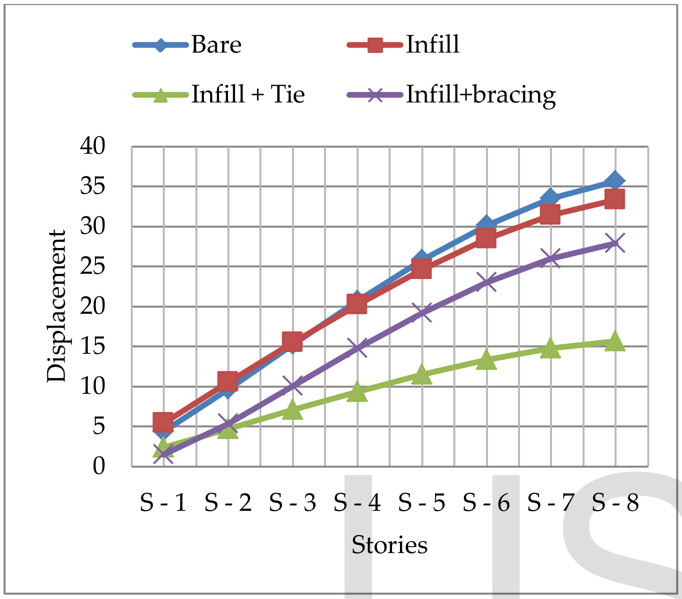

Fig.21.Displacement in X-direction of different models

7.3.2.2 Y-Direction

TABLE 15 DISPLACEMENTS IN Y-DIRECTION OF DIFFERENT MODELS

Storey	Bare	Infill	Infill + Tie	Infill +bracing
S - 1	5.93	5.76	3.047	1.9
S - 2	12.19	10.18	5.523	5.7
S - 3	19	14.41	8.012	9.49
S - 4	25.66	18.52	10.387	13.48
S - 5	32.24	22.6	12.758	17.43
S - 6	38	27	14.802	20.92
S - 7	43.12	29.12	16.552	23.87
S - 8	46.18	30.94	17.624	25.68

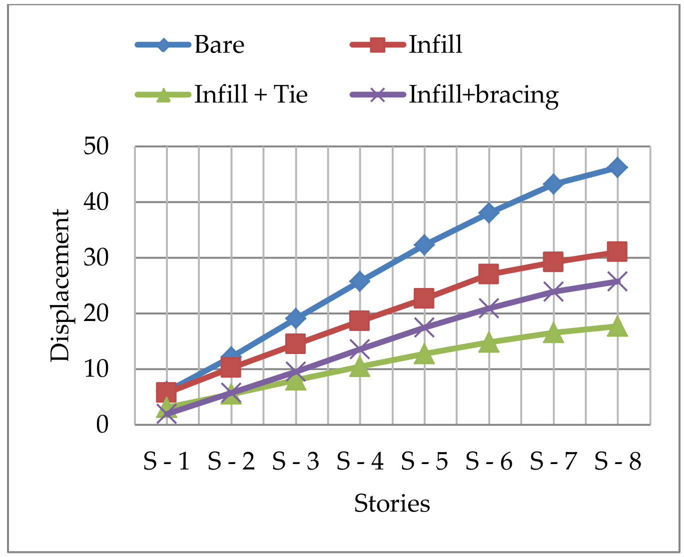

Fig.22.Displacement in Y-direction of different models

8 Results and Discussion

The results of the present study show that peripheral masonry infill wall along with tie beam and RCC X-bracing has very important effect on structural behavior under seismic forces.

8.1 For bottom storey columns the following Magnification Factor has been investigated for various load combinations and is discussed below.

8.1.1 From above analysis of group I column following points are observed.

R1) Max. Axial force Ratio is 1.65 for comb. 1.5(DL+LL), max. Moment Ratio about y-axis is 1.83 for comb. 0.9DL-1.5EQx and max. Moment Ratio about x-axis is 3.78 for comb. 1.5(DL+LL).

R2) Max. Axial force Ratio is 1.36 for comb. 1.5(DL+EQy), max. Moment Ratio about y-axis is 0.68 for comb. 1.5(DL+EQx) and max. Moment Ratio about x-axis 1.06 for comb. 1.5(DL+EQx).

R3) Max. Axial force Ratio is 1.47 for comb. 1.5(DL+LL), max. Moment Ratio about y-axis is 1.05 for comb. 1.2(DL+LL-EQx) and 1.2(DL+LL+EQy) and max. Moment Ratio about x-axis 1.48 for comb. 1.5(DL+LL).

8.1.2 From above analysis of group II columns following points are observed.

R1) Max. Axial force Ratio is 1.8 for comb. 0.9DL+1.5EQy, max. Moment Ratio about y-axis is 1.78 for comb. 0.9DL+1.5EQx and max. Moment Ratio about x-axis is 2.39 for comb. 1.5(DL+LL).

R2) Max. Axial force Ratio is 1.63 for comb. 1.2(DL+LL-EQy), max. Moment Ratio about y-axis is 1.13 for comb. 1.5(DL-EQx) and max. Moment Ratio about x-axis 1.4 for comb. 0.9DL-1.5EQx.

R3) Max. Axial force Ratio is 1.53 for comb. 0.9DL+1.5EQx and comb. 0.9DL+1.5EQy, max. Moment Ratio about y-axis is 1.61 for comb. 1.2(DL+LL-EQy) and max. Moment Ratio about x-axis 1.54 for comb. 0.9DL+1.5EQy.

8.1.3 From above analysis of group III columns following points are observed.

R1) Max. Axial force Ratio is 1.08 for comb. 0.9DL+1.5EQy, max. Moment Ratio about y-axis is 1.08 for comb.1.5 (DL+EQx), comb.1.5 (DL-EQx), comb. 1.5(DL+EQy) and comb.0.9DL+1.5EQx and max. Moment Ratio about x-axis for comb.1.5 (DL+LL).

R2) Max. Axial force Ratio is 1.07 for comb. 0.9DL+1.5EQy, max. Moment Ratio about y-axis is 0.62 for comb. 1.5(DL+LL) and max. Moment Ratio about x-axis 1.32 for comb. 1.5(DL+LL).

R3) Max. Axial force Ratio is 1.07 for comb. 0.9DL-1.5EQy, max. Moment Ratio about y-axis is 1.03 for comb.0.9DL-1.5EQx and max. Moment Ratio about x-axis 1.08 for comb. 0.9DL-1.5EQy.

8.2 The magnification factor of beams adjacent to RCC X-bracings gets increased for shear force.

9 Conclusions

As per IS 1893-2002 (Part I) clause 7.8.2, the Magnification factor 2.5 is a very conservative factor for design purpose of all columns and beams, especially for low rise building and even it is conservative for high rise building.

From above investigation done on this Magnification factor 2.5 considering different load combinations, some modified values other than 2.5 are as follows. For columns, grouping is done according to their location mentioned above and respective values are as follows.

1) When the Peripheral masonry infill wall is provided in soft storey, the Magnification factor for corner columns 3.7, for peripheral column 2.30 and for central column 1.85.

2) When the Peripheral masonry infill wall along with Tie beam is provided in soft storey, the Magnification factor for corner columns 1.36, for peripheral column 1.63 and for central column 1.32.

3) When the Peripheral masonry infill wall along with RCC X-bracing is to be provided in soft storey, the Magnification factor for corner columns 1.48, for peripheral column 1.60 and for central column 1.10.

4) When the Peripheral masonry infill wall along with Tie beam is provided in soft storey, the Magnification Factor for beams is less compared to frames without tie-beams.

5) When masonry infill wall along with tie-beam is provided in soft storey, the base shear value is more in both directions compared to frames without tie-beams.

6) Displacement in both directions is minimized when masonry infill along with tie-beam is provided compared to frames without tie-beams.

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